AN ASSISTIVE ROBOTICS CONTROL SYSTEM BASED ON SPEECH SEMANTIC RECOGNITION

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DEDICATION

Special dedication to my beloved parent Mohamad bin Nor and Ma Edayu binti Mahmud, siblings Ahmad Ameer and Siti Nur Atasha and friends.

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ABSTRACT

Since 90’s era, many researchers and organizations are working on assistive technologies to ease the disabilities people to move around freely, independence, comfort and have the capabilities to enjoy life to the fullest. Nowadays, most of assistive technologies such as manual wheelchairs are propelled by patients sitting on the chair and physically turning the large rear wheels with hand or need helpers to push the chair by handles from behind of the wheelchair. Meanwhile, most of voice command wheelchair unable to deal with an unknown word and cannot take spontaneous speech data from the native speakers. Thus, this project proposes a method of control system for an assistive robotic based on speech semantic recognition through hardware implementation. Consequently, the purpose of this project is to develop a system based on speech semantic or meaning or the interpretation of a word, sentence, or others language form that can be used for an assistive robot. The mobile robot is represented as a wheelchair and a home prototype floor plan is represented as a house with four rooms (living room, toilet, kitchen and bedroom). The mobile robot moves according to the semantic of user commands and the commands are given on Android application Arduino Bluetooth Controller. This Android application is used to catch the command using Google Voice and send the command through Bluetooth HC-05 that connected to the Arduino. Moreover, the obstacle avoidance sensor used for this project is SHARP IR Distance Measurement sensor that standby when their obstacles in front of this mobile robot and the navigation system of this mobile robot are using Simultaneous Localization and Mapping (SLAM). The effectiveness of this mobile robot has been tested using qualitative method by gathered 12 respondents to test this mobile robot on the floor plan. The total effectiveness of this mobile robot is 83%. This mobile robot is still effective but there are some parts that are still missing and need to be improved. Finally, the main contribution of this project is to help physically handicapped people such as patients who cannot move their feet by controlling using speech meanings through helpful robotics applications.

ABSTRAK

Sejak era 90an, banyak penyelidik dan organisasi sedang berusaha meningkatkan teknologi bantuan untuk memudahkan orang kurang upaya bergerak bebas, selesa dan mempunyai keupayaan untuk menikmati kehidupan sepenuhnya. Pada masa kini, kebanyakan teknologi bantuan seperti kerusi roda manual digerakkan oleh pesakit dan secara manual mengawal tayar menggunakan tangan atau mereka memerlukan bantuan untuk menolak kerusi roda mereka. Sementara itu, kerusi roda arahan suara tidak dapat mengesan perkataan yang mereka tidak ketahui dan tidak dapat mengesan arahan spontan dari loghat bahasa lain. Oleh itu, projek ini mencadangkan satu kaedah sistem kawalan untuk robot bantuan berdasarkan pengiktirafan semantik ucapan menerusi pelaksanaan perkakasan. Oleh itu, tujuan projek ini adalah untuk membangunkan sistem berdasarkan semantic ucapan atau makna ucapan atau tafsiran perkataan, ayat, atau bentuk bahasa lain yang boleh digunakan untuk robot bantuan. Robot bergerak mewakili kerusi roda dan prototaip rumah mewakili rumah dengan empat bilik (ruang tamu, tandas, dapur dan bilik tidur). Robot mudah alih ini bergerak mengikut semantic arahan pengguna dan arahan diberikan pada aplikasi *Android Arduino Bluetooth Controller*. Aplikasi *Android* ini digunakan untuk merakam arahan menggunakan *Google Voice* dan menghantar arahan melalui *Bluetooth HC-05* yang disambungkan ke Arduino. Selain itu, sensor penghindaran halangan yang digunakan untuk projek ini ialah sensor *SHARP IR* sensor yang sentiasa bersedia apabila ada halangan di hadapan robot bergerak ini daripada sistem navigasi robot bergerak ini menggunakan Penyetempatan dan Pemetaan serentak (SLAM). Keberkesanan robot mudah alih ini diuji dengan menggunakan kaedah kualitatif dengan mengumpulkan 12 responden untuk menguji robot mudah alih ini di atas pelan lantai. Keberkesanan keseluruhan robot mudah alih ini adalah 83%. Akhir sekali, sumbangan utama projek ini adalah untuk membantu orang yang cacat fizikal seperti pesakit yang tidak dapat menggerakkan kakinya dengan mengawal menggunakan makna ucapan melalui aplikasi robotik yang membantu.

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LIST OF SYMBOLS AND ABBREVIATIONS

Ω	-	Ohm
°	-	degree
A	-	Arousal
AC	-	Alternating Current
AI	-	Artificial Intelligence
ANN	-	Artificial Neural Network
APP	-	Application Programming
ARM	-	Advanced RISC Machines
ASR	-	Automatic Speech Recognition
CO	-	Carbon Monoxide
DAQ	-	Data Acquisition
DC	-	Direct Current
DoF	-	Degree of Freedom
DSS	-	Drive Safe System
EKF	-	Extend Kalman Filter
FoV	-	Field of View
GUI	-	Graphical User Interface
HMI	-	Human Machine Interface
HMM	-	Hidden Markov
ICSP	-	In-circuit Serial Programming
IDE	-	Integrated Development Environment
IoT	-	Internet of Things

IR	-	Infrared
IW	-	Intelligent Wheelchair
LED	-	Light Emitting Diode
LIS	-	Lock in Syndrome
LSA	-	Latent Semantic Analysis
M3S	-	Multiple Master Multiple Slave
MFCC	-	Mel-Frequency Cepstral Coefficients
NLP	-	Natural Language Processing
ORB	-	Oriented FAST and rotated BRIEF
PC	-	Personal Computer
PCB	-	Printed Circuit Board
POSMDS	-	POSTECH Multimodal Dialog System
PWM	-	Pulse Width Modulation
RBPF	-	Rao-Blackwellized Particle Filters
RFID	-	Radio Frequency Identification
RGB-D	-	RGB and Depth
RMF	-	Robot Motor Factor
ROS	-	Robot Operating System
RX	-	Receive
SDS	-	Spoken Dialogue System
SEMAFOR	-	Open-source Frame-semantic Parser
SI	-	Speaker Independent
SIRIUS	-	Spiiras Interface and Integral Understanding of Speech
SLAM	-	Simultaneous Localization and Mapping
SLU	-	Spoken Language Understanding
SVD	-	Singular Value Decomposition
TDS	-	Tongue Drive System

TTS	-	Text to Speech
TX	-	Transmit
USB	-	Universal Serial Bus
UTHM	-	Universiti Tun Hussein Onn Malaysia
V	-	Valence
V-SLAM	-	Visual SLAM
VFH	-	Vector Field Histogram
WIFI	-	Wireless Fidelity

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Assistive technology is a device that helps people with a disability in performing an everyday task. For example, magnifying glass and a pair of lenses is an assistive technology since its aid people with eyesight problem. There are many assistive technologies in this world until now including a specialized device such as a powered wheelchair for people who are paralysed and typing telephone for people who are deaf. When defined, assistive technology includes any piece of devices which helps in increasing the independence of disabled people. It is intended to help disabled people have the ability to see, hear, speak, learn and move about freely. Assistive technology is a growing type of technology and not new (Gaal, R P *et al.*, 1997). Many disability aids have been invented until now such as advanced technology walking products to aid people who cannot stand and even those who cannot walk. The assistive product for standing is used to aid people in the standing position while the wheeled assistive product such as wheelchair help the disabled people to increase the independence to move easily and free indoors and outdoor (World Health Organization, 2004).

Semantics is a field of linguistics that focuses on the meanings of the word and language counting the symbolic use of language. Semantic also describes the multiple meaning of words as well. The higher level of semantic language is known when there understanding of the semantic uncertainties such as figurative language and multiple-meaning of a word (Price, C.J., 2012). Two terms correlated to semantics are connotation and denotation. The connotation referred to the meaning that related or connected or the secondary meaning of the word of expression to the first or the primary meaning. The connotation of words covers all of the feeling and impression that follow with the use of the word. Whereas, denotation is the literal or primary meaning of the word compare to the feelings or the ideas that the word suggests. In general, semantics is the learning and study of how language is used metaphorically and accurately to deliver the meaning. There is some example of semantics. A child could be called a kid, child, son, daughter, boys, and girls. For example word the "run" comes with many different meaning. Run can be described as physically running, depart or go such as "I have to run.", can be run a business and many more.

One of the mobile robot problems is, it is impossible for a mobile robot to be placed at an unfamiliar location in an unfamiliar environment and for the robot to incrementally create a consistent map of this environment while concurrently deciding its location within this map (Bailey, T. and Durrant-Whyte, H., 2006). Simultaneous Localization and Mapping (SLAM) is a computational problem that builds and update the map of the unfamiliar or unidentified surrounding or places whereas it is concurrently keeping track of an agent's position within it. Though, SLAM also has to estimate the position of the agent or the robot and the map of the surrounding at the same time. In this project, in order to achieve the independence of the mobile robot to moves around freely autonomously, SLAM should work together with a mobile robot. In general, localization is known as estimating the position at the given map. Whereas, a mapping is the understanding of the map by given position. SLAM can be a little difficult because of the map are required for localization and mapping, the good position estimate is needed (Davison, A.J. *et al*., 2007).

This research work describes the development of assistive robotics control system based on speech semantic recognition for disabled people especially paralysed person. The language used for the command in this system is the Malay language. Therefore, it is suitable for Malay speaker. When the user has desires or wants to go to some places, that user say the related word to the mobile robot and the mobile robot has to find the location itself by using visual SLAM (V-SLAM). When the user expresses their desires such as "makan", "minum" and "lapar", the mobile robot will go to the kitchen. This mobile robot also mounted with SHARP IR Distance Measurement sensor that acts as the obstacle detector in front of the wheelchair when it moves to a certain location.

1.2 Problem statement

The problem statements of this project are as follows:

i. Most assistive robots nowadays are conducted using hand control, joystick or voice command direction control such as left, right, up and down but not using an autonomous wheelchair that can find the location itself according to the patient need and desires.
ii. Wheelchair usually needs other people to push or the patients itself to move it. However, there also a patient who is semi-paralyse and no one around them. Hence, with the help of this control system, the independence of the disabled people is improved.
iii. The voice or speech-controlled wheelchair usually got a few issues such as low understanding of the meaning rate and cannot take spontaneous speech data from the native speakers such as in Malay languages. Furthermore, that system is unable to deal with an unknown word. This research project is helping the speech-controlled wheelchair to increase the intelligence of speech-controlled wheelchair system by using speech semantic control.

1.3 Research objectives

The main objective of this project is to develop an assistive robotics control system based on speech semantic recognition.
The sub-objectives of this project are as follows:

i. To design and develop a control system based on speech semantic for an assistive robot.
ii. To evaluate the effectiveness of the assistive robot and its speech semantic control system.

1.4 Research scopes

There are four main limitations for this project:

i. Parameters:
   - The speech semantic recognition system is for Malay speakers.
   - Five simple keywords at three locations.
   - “Makan”, “minum”, “dahaga”, “lapar” and “peti ais” for kitchen.
   - “Buang air”, “mandi”, “basuh muka”, “wuduk” and “gosok gigi” for toilet.
   - “Katil”, “tidur”, “rehat”, “tukar baju” and “solat” for bedroom.
   - This project is implemented at a significant place such as house.
   - The mobile robot represents a wheelchair, and floor plan prototypes represent house.
   - The effectiveness of this research is tested using qualitative analysis.
   - 17 respondents from UTHM’s students were picked to test the effectiveness of this system.
   - 19 questions for questionnaire have been prepared and shared to the respondents during the testing session.
   - This research project is being tested prototypes only to prove the SLAM method and speech semantic method used.

ii. Application:
   - This project focuses on a mobile robot and its speech semantic control system.

iii. Human user
   - Disabled person that is using a wheelchair.

iv. Platform and Sensors
   - Arduino Mega 2560 Microcontroller
   - Android Bluetooth Controller Application
   - SHARP IR Sensor
   - Pixy CMUCam5

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